LANGLEY AERONAUTICAL LABORATORY
LANGLEY FIELD, VA.

AMES AERONAUTICAL LABORATORY
MOFFETT FIELD, CALIF.

LEWIS FLIGHT PROPULSION LABORATORY
CLEVELAND AIRPORT, CLEVELAND 11, OHIO

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
1724 F STREET, NORTHWEST
WASHINGTON 25, D. C.

TELEPHONE: LIBERTY 5-6700

TRENDS IN NACA RESEARCH AND DEVELOPMENT

By

Hugh L. Dryden, Director
National Advisory Committee for Aeronautics

Presented at SAE National Aeronautics Meeting
Biltmore Hotel, Los Angeles, California
October 5, 1951

For the third time in its history, the trend of NACA research and development is heavily toward the support of the military aeronautical program, which is the chief hope for the preservation of the peace of the world. Over the years since the creation of the Committee as an independent agency of the government to "supervise and direct the scientific study of the problems of flight with a view to their practical solution", there has evolved an intimate relationship between the aircraft industry, the military agencies, and NACA, such that the contributions of each group are thoroughly interwoven with those of the others in the final product. All work together to attain superiority in performance and military effectiveness of our air weapons.

NACA has been primarily responsible for the conduct of an adequate research program to lay the groundwork for continuing progress by the designer and builder. This assignment of primary responsibility has not meant that no one else should perform research nor that NACA was restricted from completing work on some problem by testing its research findings by practical application.

Numerous university groups engage in fundamental research in the aeronautical sciences. The NACA led in sponsoring aeronautical research by educational groups, and today supports almost a million dollars worth of such work each year. Support of research performed by universities is also forthcoming from the military services, and the military services themselves conduct a great deal of research, especially in such fields as electronics, armament, aeromedicine, geophysics, and others not within the scope of NACA's responsibility. The aircraft industry, the airplane and engine manufacturers also conduct research. There is an exchange of programs, results, and views and a resulting correlation and coordination of research effort in the NACA executive committee and its twenty-seven technical subcommittees and in the committees of the Research and Development Board of the Department of Defense.

Let us examine a little more closely how the work of the NACA ties in directly with the planning and procurement of the military services in the field of aircraft and missiles. The start of such planning and procurement is, I suppose, a blueprint of what will have to be done to make good the military commitments of the United States. These commitments include the defense of the continental United States and our other territories, the support we have promised to the defense of those European nations who wish to live in a free world, and a successful completion of the action in Korea.

Next comes the writing of the specifications for the airplanes and missiles and power plants which will be needed, as well as the many other weapons and items of equipment for which NACA has no responsibility.

In the establishment of requirements for aircraft and missiles, and the specifications to meet them, NACA counsels as to what kind of performance the manufacturers should be able to design and build into the models ordered. Today they can make fighter airplanes that flirt with the speed of sound, using the 7,000-pound-thrust engines which are manufactured today. Tomorrow, on the basis of new aeronautical knowledge built up since today's airplanes were conceived, they can design and manufacture supersonic airplanes with qualities which the military need in tactically useful airplanes. Sometimes, perhaps, the industry must think that the counsel we give the military services is altogether too optimistic, but we are ready to roll up our sleeves to help make good on the projects embodying the frontiers of knowledge, and the industry has a way of translating the possibilities into actualities.

Then comes the design competition. Here NACA's contribution is to supply the results of basic and applied research which bear on the problems which the designer must solve. The design of aircraft is an art, the art of securing the best compromise between the desired and the possible. Unfortunately, the aircraft which is designed for maximum speed has reduced range and reduced maneuverability and similarly conflicts arise in many other aspects of the design problem. Ingenuity and inventive application are necessary ingredients of a successful prototype. Yet the designer must base his solutions on sound technical knowledge, and a great deal of this knowledge can be supplied by NACA. If we are on the job, we will foresee the problems of the future and work toward their solution to be ready when the designer needs the information. We review the state of knowledge for him in technical conferences and we advise on the special problems of his design.

The design proposals are evaluated by the military services and one or more contracts awarded for prototypes. In practically every important project the military services at some stage request the use of NACA equipment and skills on specific problems. Models are constructed as the engineering work progresses for measurements in high-speed wind tunnels at large Reynolds numbers, and for rocket-propelled model tests. Power plants under development are installed and operated in the altitude tanks under conditions encountered in flight at high altitude. Engineers of the company whose models are under test are on hand, and, as the information is secured, modifications are considered. In every case it is the company engineer who decides what, if any, changes will be made. We are as helpful as possible, but NACA is not in the business of designing or constructing airplanes. There is more than enough research to be done.

Then the prototype flies. If you think the research and development job is then finished, let me tell you the story in terms of one of the best airplanes to be built during the last war. Up to and through the prototype stage, the manufacturer invested something like a million and a half engineering man-hours in this airplane. During this same period, NACA spent almost a hundred thousand engineering man-hours on the airplane. During the period this airplane was in production - and a good many of this particular model were built - the manufacturer spent almost five million engineering man-hours to secure improvements. During the same period NACA spent approximately a half-million man-hours to the same end.

In this life cycle of an airplane, so unfamiliar to the lay public not associated with it, there are encountered the three principal categories of NACA research. The first is the truly basic research, the exploration of new fields, and the search for more complete understanding of older fields. This is the work which can lead to radically new developments and which will pay off in the design of future aircraft and power plants. Our present aircraft embody the results of basic research carried out years ago which now seems so familiar to the designer that he forgets it was ever new.

The second category is applied research directed at the foreseen problems of the aircraft now being designed. The problems to be worked on are crystallized from the thinking of designers, users, and research workers. This is the research which can be swiftly translated into practice, embodied in actual aircraft at an early date, granted only that sufficient manpower and funds are provided. This is the work which makes possible an increase in thrust of the next engine, and improved stability and controllability of the next airplane.

The third category is specific research on the problems of the prototypes now building or flying. The problems encountered in a production airplane automatically assume top priority; those of a prototype produce equal pressures. This work is essentially a part of the development of the specific airplane or missile.

The three categories differ principally in the time scale and, as is natural in a period of tension and large production of aircraft, the trend of NACA research is toward a shorter term on the average. This trend has some elements of danger, and I wish to discuss briefly current consideration of NACA research policy and its implementation. It will be recalled that ten years ago just prior to World War II, the pressure on NACA to concentrate on applying available scientific knowledge to the immediate improvement of airplanes scheduled for war production soon became so great that the basic research programs were cut and cut until they represented hardly 10 percent of our total work. The result was that we came out of that war with a serious deficiency of research information, especially in supersonic aerodynamics and jet propulsion.

The trend to short-term specific investigations must not occur again to the same degree as during World War II. To do so will undermine the research foundation upon which our future development program must be built. In the current situation of a probable extended period of international tension and the dependence of the free world on the leadership of the United States we must continue the program of fundamental scientific research initiated after the close of World War II and at the same time provide for the speedy refinement of production airplane designs, the correction of troubles, and the essential day-to-day improvement of current types. This is the stated policy of NACA reflected in its budget submissions and operating practices. Its full implementation is contingent on increased financial support and the continued sympathetic consideration of the military agencies in the calling up of reservists and of the draft boards in the deferment of specialized personnel.

The experience of thirty-six years has taught that a moderate effort on specific investigations of current airplanes and missiles insures a more realistic and effective conduct of the basic and applied research, promotes mutual understanding between research scientists and designers, and secures early application of research results. It is greatly in the national interest that the knowledge and skills of NACA scientists be brought to bear on the critical problems of current prototype and production airplanes and missiles.

It is too much to expect that any citizen, even an NACA research scientist, administrator, or Committee member will refuse to help make our present airplanes as good as they can be made. What is required is a balanced effort within a total effort commensurate with the need. The total effort, in manpower and money, needed for the research and development to insure the qualitative superiority of our air weapons is small relative to the total effort being expended to build up our air power.

At least by comparison, NACA is in a better position today to undertake this double-barreled task than on the eve of World War II. Then we had one laboratory, and something less than 600 research scientists and supporting personnel. Today we have three laboratories, and a little more than 7,000 research scientists and supporting personnel. With the research equipment we now have, or are in the process of acquiring, we should have most of the essential tools. Inevitably we shall have to increase the number of our people, perhaps by 50 percent, but nothing like the way we had to expand a decade ago. In the light of the tremendous technical changes brought about by jet propulsion and consequent supersonic speeds, the innumerable new problems added to the old ones, and the three-fold expansion of the military research and development program, such a modest expansion of NACA effort may appear too small. The expansion is in fact limited by the saturation of use of critical facilities and shortages of technical manpower rather than by the needs of the expanded military program.

The trends in research policy which have just been described are reflections of the trend of technical developments in the aeronautical sciences and their applications to airplanes and missiles now being designed. These technical trends can be discussed in an unclassified paper only in very general terms, and space limits the discussion to a few examples.

The first obvious trend is that toward aircraft of greatly increased performance. It seems probable that airplane speeds may be increased as much in the next five years as in the whole history of human flight up to World War II. Experimental flights with piloted aircraft at transonic and supersonic speeds have been made with increased frequency during the past year. It has been clearly demonstrated that aircraft operations will ultimately be conducted throughout the entire transonic range. Information is becoming available to permit the development of airplanes capable of further penetration of the transonic and low supersonic speed ranges with fewer operational limitations. The limited successes already realized have brought to light many detailed problems which can be solved by continued research. These relate to all phases of transonic and supersonic stability, control, maneuverability, and performance, and the landing and take-off behavior of the new and unconventional high-speed configurations. An exceptionally important development is the transonic ventilated wind-tunnel throat invented by Stack and his associates, which makes possible the study of transonic problems in wind tunnels, hitherto impossible because of the choking of the conventional wind tunnel as the speed approaches the speed of sound. All high-speed wind tunnels in this country will be converted to transonic operation as rapidly as the necessary funds are supplied. Tremendous improvements in the aerodynamic characteristics of aircraft configurations at transonic and supersonic speeds have already been made, including large drag reductions and imporved stability and control. A striking feature of the results is the sensitivity to details of design which forecasts a necessity for much additional specific testing.

Technical development is moving in a direction to throw heavier responsibility on the structures design group. Structural problems may become a limiting feature in the future and NACA is taking steps to secure the necessary tools and to place increased effort in this area. The requirements of long-range, high-speed, high-altitude operations often result in a relatively flexible airplane structure. This gives rise to important mutural interactions between aerodynamic loads and structural deflection, as well as to important transient dynamic loads in gusty air and on landing. Furthermore, the flexible structure may vibrate unduly or exhibit the catastrophic phenomenon of flutter. These phenomena may be studied by investigations of dynamically similar models as well as by more fundamental studies of the component aerodynamic and structural behavior under dynamic conditions. A second structural problem which will in time become the major problem limiting further gains in airplane performance is that of the distortion of the structure and changes in physical properties of materials arising from the heating of the surface of high-speed aircraft and missiles.

The dependence of missiles on automatic stabilization and control and guidance equipment has led to more intensive study of the matching of the aerodynamic characteristics to the characteristics of the automatic equipment. Similar problems are now arising in piloted aircraft, where the high performance places demands on the pilot beyond his physical capacities. His vision is extended by radar, his muscles by power boost in the control system, and his slow reaction time is compensated by automatic equipment. Furthermore, automatic equipment can be used to improve the flying qualities of aircraft, even when there is no question of supplementing the physical abilities of the pilot. This trend in technical development yields a host of new problems as well as the opportunity for increasing the utility of high-performance aircraft.

Recent improvements in gas-turbine-engine performance through adoption of afterburners on turbojet engines for thrust augmentation have complicated the problem of engine control. The technical characteristics of jet engines require operation near the safe limits of speed and temperature. Application of turbine-propeller engines likewise presents a control problem which places an intolerable burden on the operator unless quick-acting, accurate, stable, and safe control systems are fitted to the engines. The solution of these problems requires equipment for operating the complete system under altitude conditions and the use of analogue computers for rapid study of the effects of design changes.

In order to obtain high performance, the hot parts of jet engines are made of high-termperature alloys which contain alloying metals either not found in the United States or in limited supply. A major trend in engine development is the reduction of strategic material content to permit large-scale production. An important part of NACA research is devoted to this problem, ranging from basic research on why materials behave as they do to substitute materials and to turbine blade cooling. Turbine blade cooling offers promise either of removing practically all of the strategic materials from the blades while retaining present performance or of substantially increasing output for applications for which the strategic materials can be allocated in sufficient quantity.

As another illustration of the trend in technical development, mention may be made of the increased attention being given to the research underlying the development of helicopters of improved performance which has resulted from the great utility of this type of aircraft demonstrated in recent military operations. Attention is being given to high-speed rotors, jet rotors, stability and control of multi-rotor helicopters, flying qualities, and vibration characteristics.

The pattern of technical development has changed very decidedly since the days of World War II. Progress in performance then proceeded at what now seems to be a relatively slow and orderly pace. A reasonable goal was a speed advance of 100 miles per hour or less or a modest increase in rate of climb or altitude. The engineering advances required were modest, and much effort was devoted to the study of changes which increased the maximum speed 20 or 30 miles per hour. The problems of compressibility effects were still new and the sonic barrier seemed very real. Much effort produced a little closer approach to the critical Mach number.

Today we are contemplating, and with some assurance of success, striving toward very large gains in performance. The chance of success is greatly dependent on extensive detailed knowledge; small changes of contour may make large changes in performance. The design compromises are much more difficult than before. As a result we have found that the step-up in military research and development leads first to demands for expedited applied research in many critical areas and at a much later stage to requests for tests of specific configurations. The problems are so many, and the cost of failure to advance so great, that accelerated effort in the critical problem areas is a priceless insurance.

These then are some of the trends of NACA research and development to meet NACA's responsibility in the current situation. We of NACA pool our skills with those of our industry and military colleagues to increase greatly the military strength of the United States and its allies with the hope of maintaining peace by deterring aggression. If, nevertheless, war should come, the joining of a great research and development potential with demonstrated production abilities will bring us victory. To these efforts of free men to maintain their freedom, we of NACA will give our best.

* * * * * * * * *

October 5, 1951